

The Impact of NSCAT Data on Simulating Ocean Circulation

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Abstract

Wind taken from the National Aeronautics and Space Administration (NASA) scatterometer (NSCAT) is compared with the operational analysis from European Center for Medium-Range Forecast (ECMWF) for the entire duration (about 9 months) of the NSCAT mission. Spectral analysis of the NSCAT data (both along satellite swaths and gridded fields) shows a higher energy content than that of the ECMWF analysis, particularly in the high wavenumber region. Both NSCAT and ECMWF winds are then used to drive an eddy-resolving North Atlantic Ocean model with a resolution of $1/6$ degree and 37 vertical levels. Results show that in the Gulf Stream region both the NSCAT and ECMWF wind-driven model compare well with TOPEX data, while in the subtropical region the NSCAT wind-driven model simulates a more realistic synoptic variability of the sea surface height field.

Introduction

Marine surface wind products distributed by numerical weather prediction (NWP) centers, such as the National Center for Environmental Prediction (NCEP) and ECMWF, are routinely used in the ocean modelling community for driving numerical models of the ocean. However, the wavenumber energy content of these analyzed winds follow the theoretical and measured k^{-2} power law (Freilich and Chelton, 1986) only down to the spatial scale of 500 km. Due to the finite grid size of those NWP models and the approximation of subgrid-scale parametrization, it is found that the analyzed wind energy level below 500 km is much too weak compared to observations (Milliff et al, 1996). The satellite scatterometer wind measurements, on the other hand, have widely spaced and uneven spread of swath patterns, and therefore have to be interpolated between swaths before it can be used for driving ocean models.

In this article, level 2.0 scatterometer wind data obtained from NSCAT (JPL, 1997) at 10-m height is first compared with ECMWF data ($1^\circ \times 1^\circ$ at 10-m level). A Gaussian weighted gridding scheme is then applied to generate a gridded product which captures the high wave-

number wind energy that is previously missing from the operational winds (Milliff et al, 1996). The resulting wind field and the original ECMWF wind are then used to force an ocean general circulation model (OGCM) and the results are compared with TOPEX/POSEIDON observations to determine the impact of the NSCAT wind on simulating the North Atlantic ocean circulation and its variability.

A Comparison Between NSCAT and ECMWF Winds

Our analysis of the NSCAT winds begins with a power wavenumber spectrum of the along-track wind data covering the entire period of the NSCAT mission from 9/15/96 to 6/30/97. We will be concerned only with the spectrum of zonal wind component, as our studies and others (e.g. Freilich and Chelton, 1986) have shown that the meridional component have similar properties. The region of interest concerns the Atlantic ocean starting from 100°W to 20°E and 35°S to 80°N . No distinction is made between the ascending and descending tracks in the calculation, as our analysis shows no significant deviation from symmetry. The power spectrum and its corresponding chi-square 95% confidence interval is shown in Figure 1. The spectrum shape generally follows the well-known k^{-2} slope for wind speed log power spectrum (Freilich and Chelton, 1986), up to about 500km. For wind scales less than 500 km, the slope becomes flat, and this increase in energy is consistent with the usual behavior expected from a noise-dominated spectral tail. The comparison with the ECMWF analysis in the same region and identical time period shows that raw NSCAT wind spectrum is more energetic, especially in the high wavenumber region having spatial scales of 500 km or less. A blended NSCAT wind product (Cheng et al., 1998) is then generated and exhibits the required energy boost in the high wavenumber that is expected of the scatterometer derived wind fields. Moreover, the blended wind spectra continues to have the expected k^{-2} power law well into the high wavenumber regions.

The Response of the North Atlantic Ocean Circulation to NSCAT and ECMWF winds

The impact of this blended NSCAT wind field on the ocean circulation and variability is investigated through an eddy-resolving OGCM based on the Parallel Ocean Program (POP) developed at Los Alamos National Laboratory (Dukowicz et al., 1993). This ocean model evolved from the Bryan-Cox 3-dimensional primitive equations ocean model (Bryan, 1969), developed at NOAA Geophysical Fluid Dynamics Laboratory (GFDL), and later known as the Modular Ocean Model (MOM; Pacanowski et al.,

1991).

The model domain covers the Atlantic basin from 35°S to 80°N and from 100°W to 20°E and is formulated on a spherical grid with horizontal resolution of approximately 1/6° (0.1875° in longitude and 0.1843° in latitude), and 37 vertical levels and integrated for a total of thirty years forced with climatological seasonal air-sea fluxes (see Chao et al., 1996 for a detailed description). With the September conditions at the end of this 30-year spinup as the initial conditions, two 290-day integrations have been carried out corresponding to the period of the NSCAT mission. Model output in the form of the synoptic sea surface height field are saved at 3 day intervals, and only the last 4 months (120 days) of SSH fields are analyzed. We emphasized that the only difference between these two integrations is the wind forcing, one from the gridded NSCAT as described in the previous section and the other from ECMWF analysis.

To study the synoptic ocean response, particularly in the mesoscale, we concentrate on two regions in the North Atlantic, the Gulf Stream region (region I) with coordinates 50W-70W, 30N-40N and the eastern subtropical region (region II) with coordinates 20W-40W, 10N-20N. Figure 2a shows the variance plot as a time series for the patch near the subtropical region at 20W-40W, 10N-20N. Clearly, NSCAT SSH variability is significantly higher than the ECMWF SSH variability by about 50%, and closer to the much higher TOPEX SSH variability. On the other hand in Figure 2b, the NSCAT SSH variability fit to TOPEX variability is comparable to that of the ECMWF, indicating that the NSCAT model did just as well as the ECMWF model in the Gulf Stream region. The corresponding time-averaged wavenumber spectrum for these two patches are shown in Figure 3. It is clear that in the West African region significant variability shows up across all wavenumbers, whereas in the Gulf Stream, both model spectra fit the TOPEX computed spectrum quite well.

Summary

A new gridded wind product is created that is a hybrid between the NSCAT scatterometer wind and ECMWF operational wind. This dataset is shown to have a high energy content in the high wavenumber that is consistent with that observed from along-track spectral analysis of the NSCAT wind data, hence more realistic when compared with the weak highwavenumber energy content that is present in the ECMWF winds alone. This NSCAT wind product is then tested on an eddy-resolving Atlantic model with 1/6° resolution and 37 vertical levels, and its sea level response in the North Atlantic is compared with those derived from the same model with ECMWF wind forcing and validated with TOPEX/OPOSEIDON sea level observations. Within an integration time period of 290 days equal to the entire duration of the NSCAT mission, an observed change in the synoptic sea level variability of about

40-50% was detected in the eastern subtropical region, indicating that NSCAT winds does provide significant impact for some regions with this ocean model.

Acknowledgments

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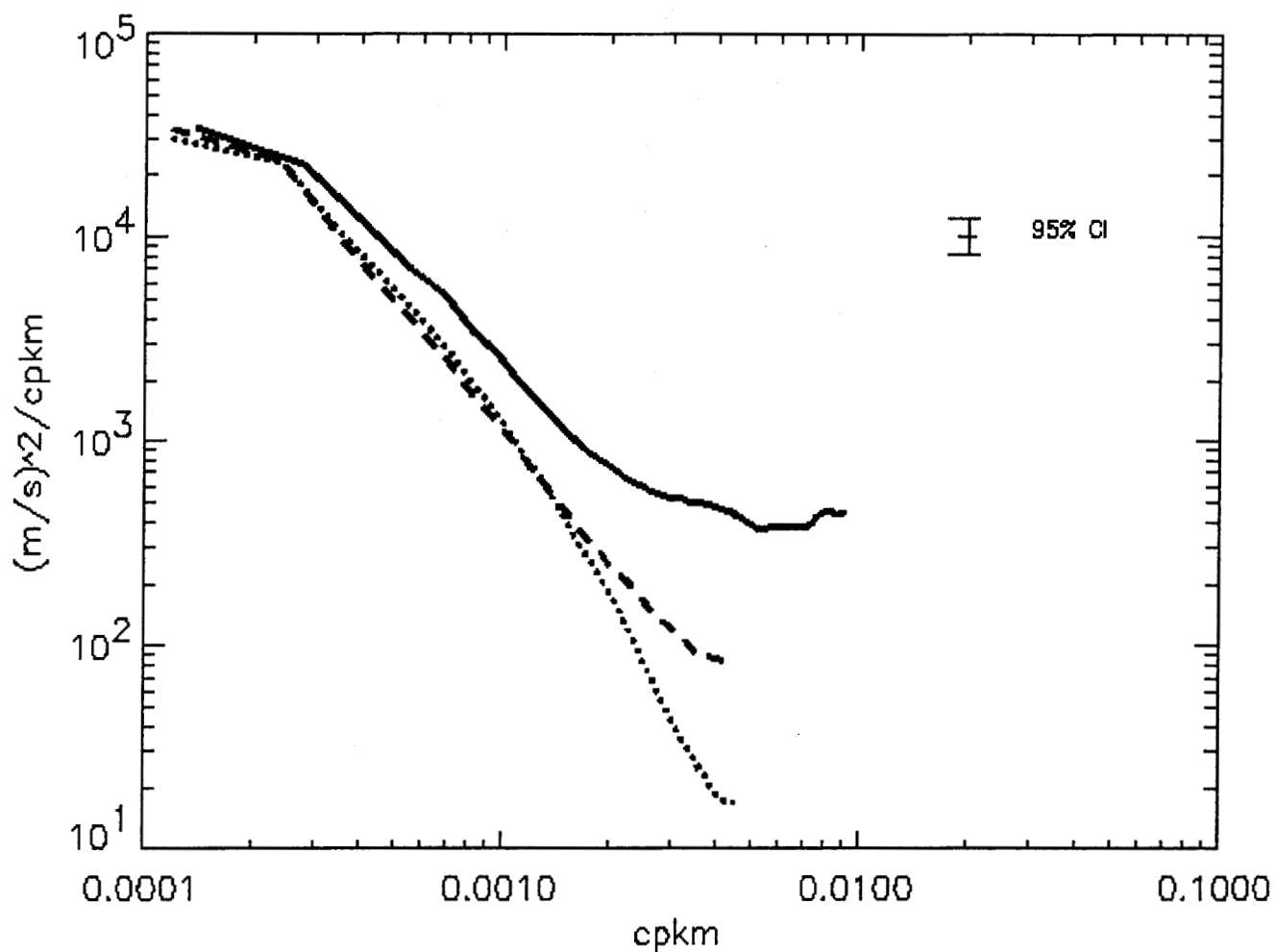


Figure 1. Power wavenumber spectra from NSCAT along-track zonal wind (solid), ECMWF zonal wind (dot), and gridded NSCAT blended with ECMWF wind (dash). The 95% confidence interval is computed from the original NSCAT along-track data.

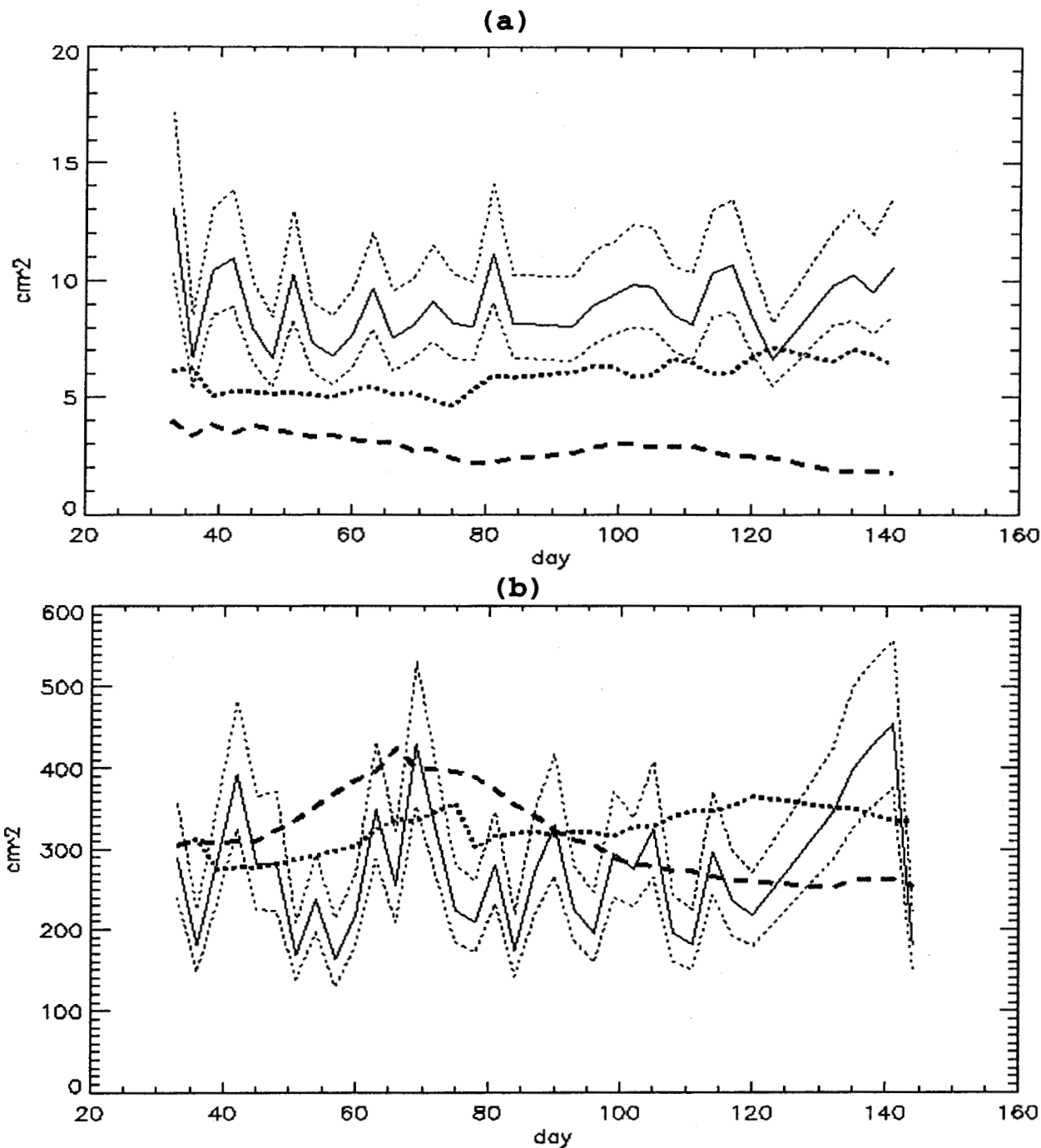


Figure 2. (a) Variance plot of the eastern subtropical region (20W-40W,10N-20N) as a function of time (b) Corresponding variance plot for the Gulf Stream region (50W-70W,30N-40N). Dotted lines indicate the SSH variability of the NSCAT-driven model, dashed lines that of the ECMWF-driven model, and solid lines represent the SSH variability computed from TOPEX/POSEIDON along-track data. 95% confidence envelope for the TOPEX SSH variability is also given.

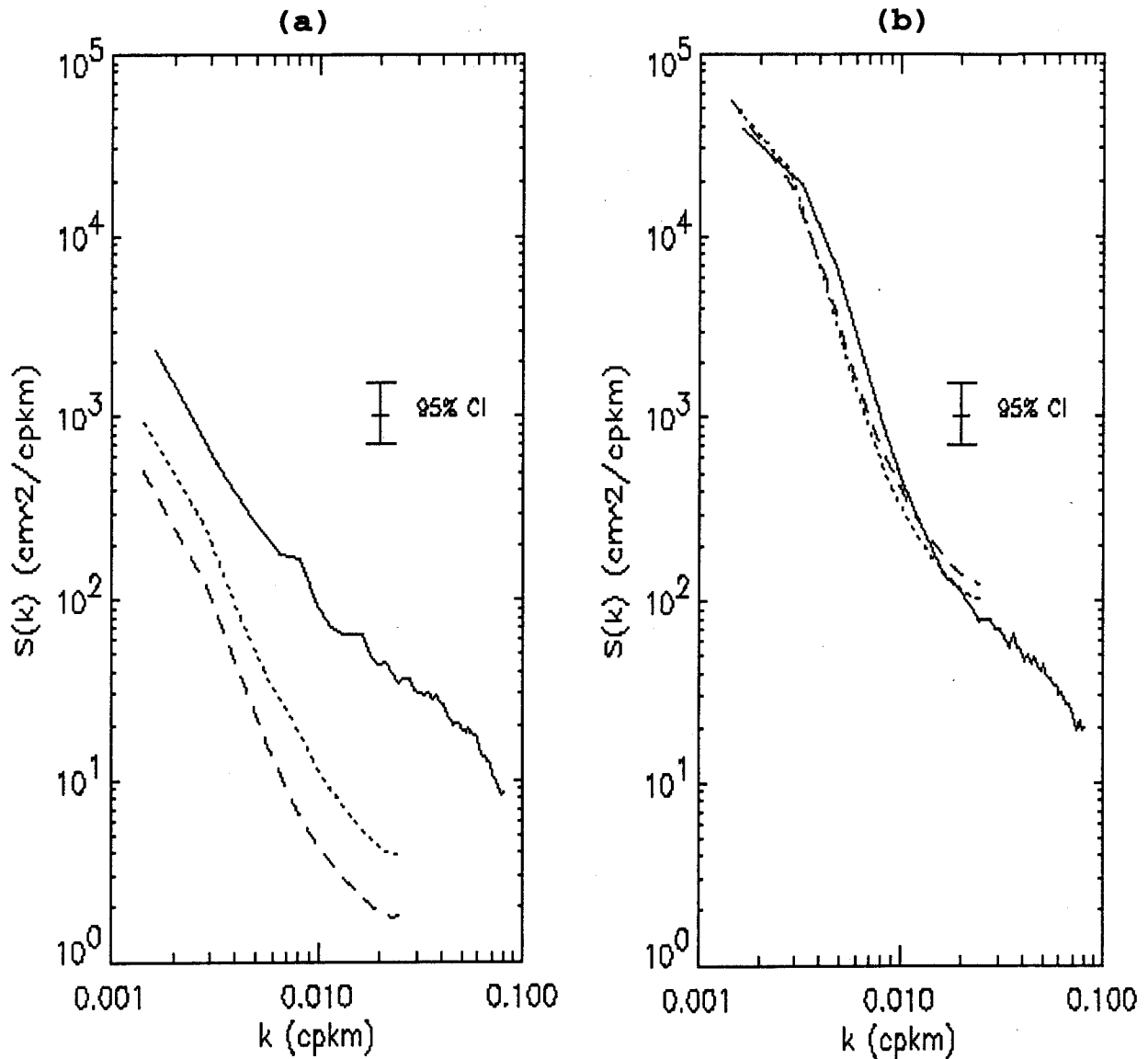


Figure 3. (a) Wavenumber spectrum for the subtropical region averaged over the last 4 months of the integration time. (b) Corresponding wavenumber spectrum for the Gulf Stream region. Dotted lines indicate the SSH spectrum of the NSCAT-driven model, dashed lines that of the ECMWF-driven model, and solid lines represent the SSH spectrum computed from TOPEX/POSEIDON along-track data. 95% confidence interval is computed based on TOPEX SSH spectrum.